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A STUDY ON THE POSSIBLE USE OF CHAT
AND TAILINGS FROM THE OLD LEAD BELT OF
MISSOURI FOR AGRICULTURAL LIMESTONE

by

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SUPERFUND RECORDS

7ES

Site	Big River
ID#	1700 8461 09
Break.	1-8
Other.	12/83

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A Research Report
Submitted to the
Missouri Department of
Natural Resources
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spikes were incorporated into the analytical program at the University of Missouri-Rolla (UMR) and the ETSRC to validate analytical results

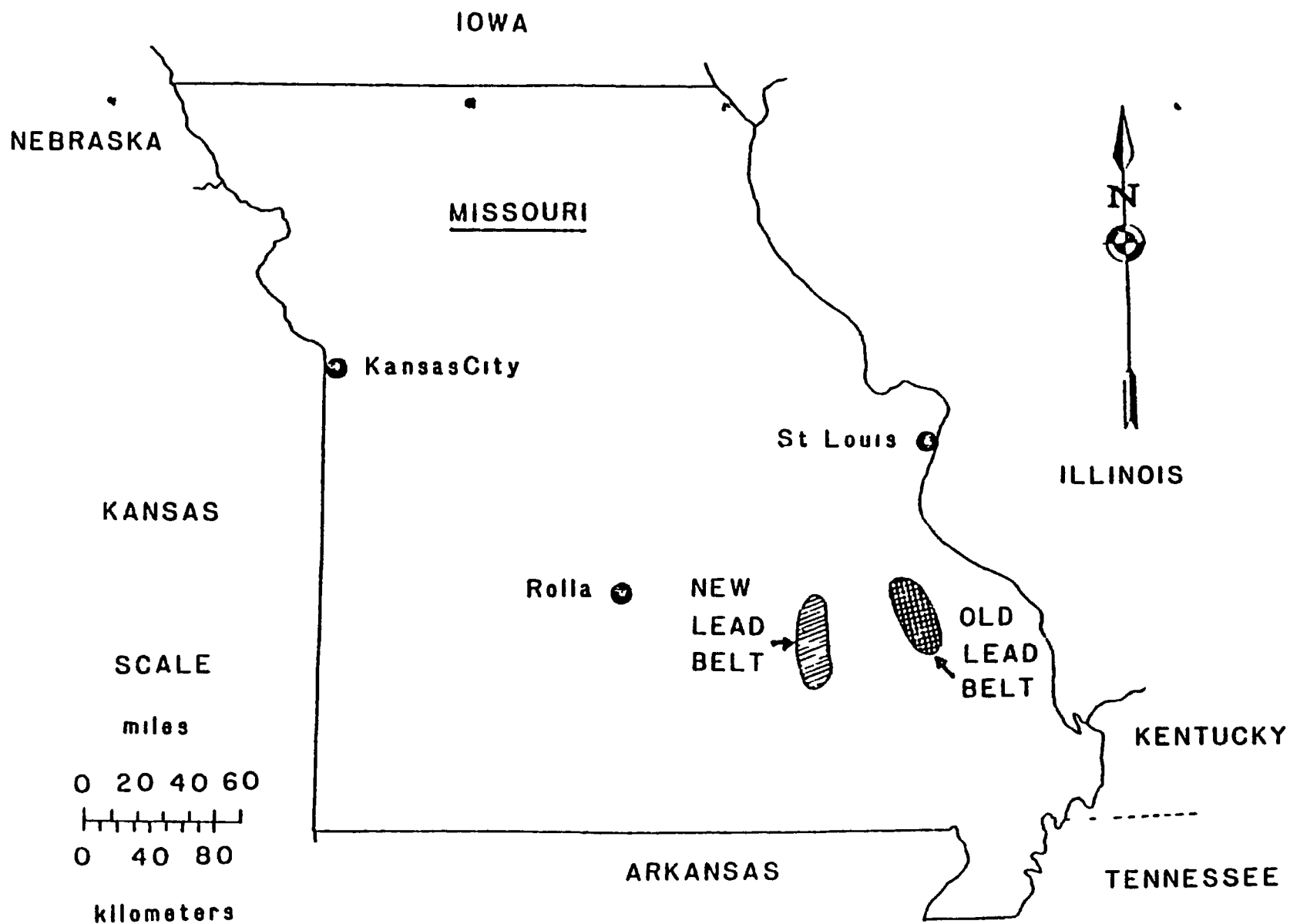
IV STUDY AREA

The study area selected for this investigation is comprised of the Leadwood, Big River, Desloge, Elvins, National and Bonne Terre tailings piles within the confines of the Old Lead Belt in St. Francois County, Missouri. The Old Lead Belt is located about 113 km (70 mi) south of St. Louis, Missouri and contains the cities of Bonneterre, Leadwood, Elvins, Desloge, and Flat River. This old mining region covers an area of approximately 285 sq km (110 sq mi) and is bordered by latitudes 38°00' and 37°49'5" and by longitudes 90°37'30" and 90°28'45"

According to a report submitted by Heyward M. Wharton to the St. Joe Minerals Corporation on 28 October 1983 (6) the acreage affected by inactive lead-zinc mining in the 'Old Lead Belt' represented 3085 acres as contrasted with the 1822 presently impacted by active or development mining operations in the "Viburnum Trend". Figure 1 provides a visual perspective of the area including its location with respect to major cities in Missouri.

The topography consists of gently rolling hills with narrow table-lands areas and alluvial plains comprise most of the topography in the Old Lead Belt, with the exception of the extreme southwestern portions of St. Francois County, which is mountainous (7). Hickory, elm, and sycamore trees compliment the lowland stream areas, while red, white and black oaks are abundant in the upland areas (8).

The climate of this region usually consists of warm, humid summers, and mild winters. Extremes of -30°F (-34°C) and 115°F (46°C) have been



LOCATION OF OLD AND NEW LEAD BELTS OF MISSOURI

FIGURE 1

recorded, but are not common to the area. Annual rainfall averages generally total about 40 inches (9).

Galena, the most important mineral ore or lead, was the principle ore mined within the Old Lead Belt of Missouri (10,11). Normal thickness of this mineralization varied from a few inches to about 61 m (20 ft). These ore deposits were horizontal, concentrated along flat shale bands or other easily permeated plains, and found in the Bonne Terre dolomite with thicknesses of nearly 131 m (400 ft). The La Motte sandstone, with thicknesses up to 400 feet, underlies this dolomite, while shale and siliceous dolomite, in thicknesses up to 152 m (500 ft) is found above it.

5

6

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waters. The two notable exceptions were 1) a sample of water taken directly from a pipe from an old drill hole (59 ppb) some distance upstream of the eroded break in the Desloge tailings pile, and b) a sample taken from the Big River at the junction with sewage effluent from the Desloge-Flat River city sewage treatment plant (54 ppb).

Sampling transects were designed to take the most representative samples of tailings (or chat) material from the unweathered portion (depth of 20 cm) of the piles in sufficient numbers to meet the Missouri DNR statistical program discussed in the methods section of the report and included in the Appendix. Sampling locations were noted by number on the appropriate tailings figures and followed by tables giving the metal values for Pb, Cd, and Zn.

The national tailings pile was the subject of a M.S. thesis by Elliott (15) and only the pertinent findings are discussed in this report. However, a copy of Elliott's thesis (15) will accompany the report as a part of the research evaluation.

Individual tailings or chat piles are discussed according to characterization by sampling data. A statistical analysis and evaluation of the different tailings piles is included at the end of this section of the report.

A Leadwood

A series of transects were established for the Leadwood tailings and chat pile located along the eastern border of the town of Leadwood, Missouri and extending slightly to the south of town. Figure 5 illustrates the samples numbering for the 98 samples taken at near-surface unweathered

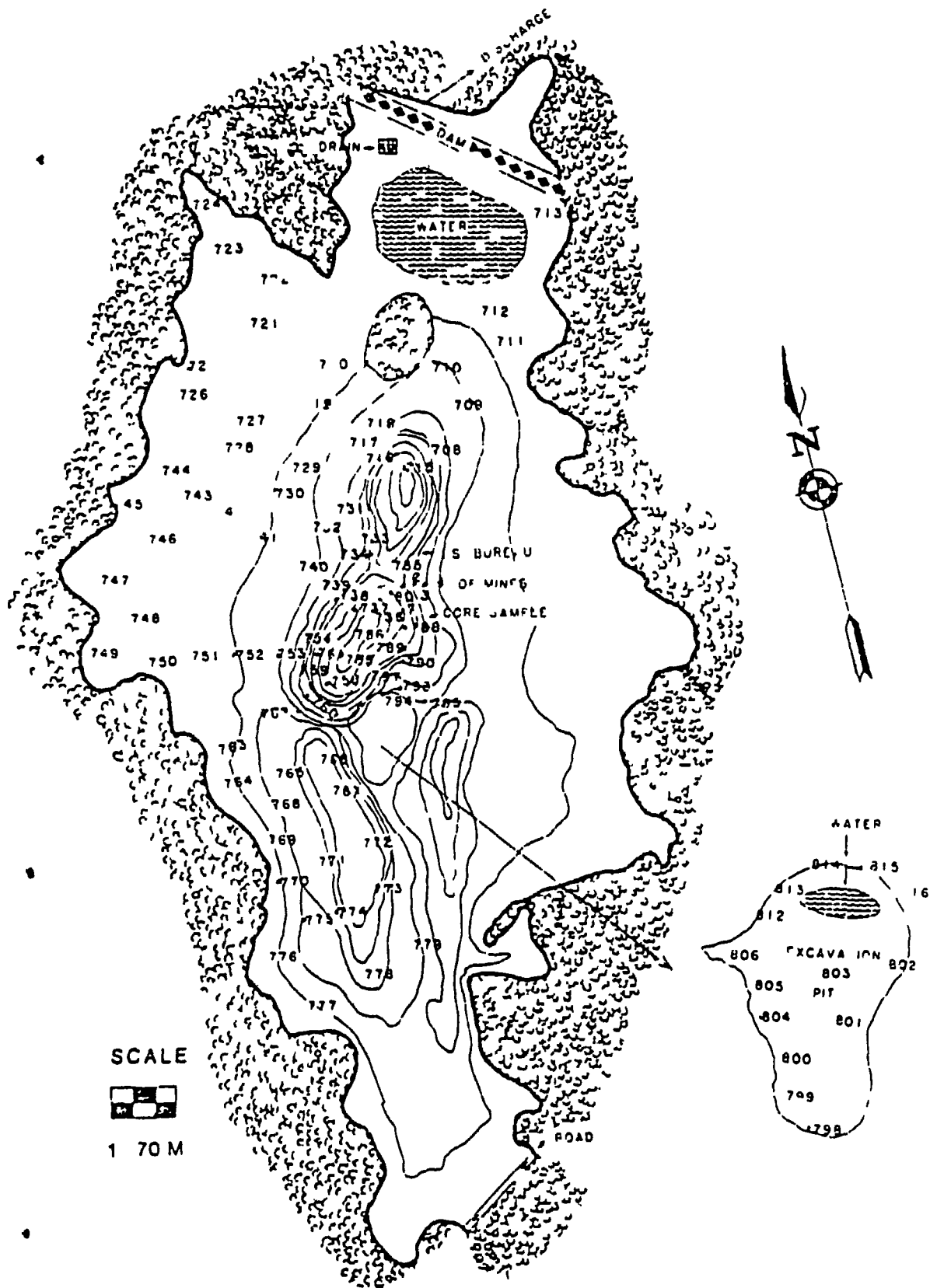


FIGURE 5 LOCATION OF SAMPLING SITES
ON LEADWOOD TAILINGS PILE

materials Table I indicates the metal concentrations for Pb, Cd, and Zn in micrograms per gram (parts per million) by sample number

Since the U S Department of the Interior Bureau of Mines was performing a research study associated with tailings deposits in the "Old Lead Belt", a cooperative effort was worked out with their research people whereby the near surface sampling results would be shared with them in return for the Bureau of Mines coring down to the bottom of the Leadwood and National tailings piles Mr Larry George, Glynn Horter and Scot Lay assisted with the coring procedure and Figure 6 illustrates the location of the hand augered samples (two-to-four foot depth) and the drill hole locations which extended to twelve feet at one location and twenty four feet at a second location to reach bedrock under the Leadwood tailings pile Table 2 gives the Pb, Cd, and Zn concentrations associated with the hand augered samples and the two coring drill holes (Courtesy of the Bureau of Mines) Table 3 gives the inductive coupled argon plasma (ICAP) analysis for the core samples at site R-1 down to 24 ft and Table 4 gives the ICAP data for the core samples at site R-2 down to 12 ft or bedrock

The highest lead values found for the Leadwood tailings pile were 17,000 micrograms per gram which came from a site close to the earthen dam at the north-eastern portion of the area The next highest sample of 13,500 ppm came from the center of the excavated pit on the south side of the main pile Shallow hand augered samples did not show a significant change in composition down to a depth of four feet

TABLE - 1
LEADWOOD TAILINGS PILE

Sample No	Total Conc ug/g		
	Pb	Cd	Zn
L708	1320	66 9	3490
L709	1880	89 7	4750
L710	1630	63 6	3550
L711	1110	40 0	2290
L712	2420	67 4	3570
L713	17000	158	8630
L714	9500	243	15200
L715	1620	88 8	4150
L716	1800		4940
L717	2310	105	5150
L718	1900	87 5	4370
L719	1780	66 0	3100
L720	2580	74 5	3530
L721	1630	49 5	1710
L722	1580	47 5	2180
L723	1510	39 5	1980
L724	2280	41 6	1880
L725	1620	37 6	1600
L726	1020	42 3	1830
L727	2590	70 6	3250
L728	1620	57 2	2860
L729	3210	115	6040
L730	1020	64 0	3200
L731	1990	111	6150
L732	1860	101	5620
L733	1630	101	5540
L734	1260	171	9720
L736	2530	98 9	4650
L737	1600	96 7	4830
L738	1630	94 2	4510
L739	1720	78 3	5720
L740	919	44 0	1600
L741	886	28 3	1040
L742	761	30 4	1050
L743	823	34 5	1340
L744	986	33 5	1300
L745	2170	83 7	7980
L746	822	75 3	5760
L747	1430	763	7820
L748	1070	596	2280
L749	890	763	3550
L750	820	547	2520
L751	1220	1610	8230
L752	2300	1870	10100
L754	2260	1720	8220

(CONTINUED)
TABLE - 1
LEADWOOD TAILINGS PILE

Sample No	Metal Conc, ug/g		
	Pb	Cd	Zn
L755	1170	1230	6060
L756	1900	1350	7060
L758	1950	995	5460
L759	4740	1120	5890
L760	920	45 2	2480
L761	1050	625	3520
L762	1880	858	4390
L763	1430	1200	6730
L764	1670	856	4480
L765	736	1010	5570
L766	3420	20 4	1710
L767	597	308	1250
L768	3290	20 3	1430
L769	3330	372	1660
L770	1400	721	3420
L771	1300	15 9	987
L772	2260	77 2	4050
L773	788	31 1	1280
L774	1120	44 3	2210
L775	916	46 7	2240
L776	2600	37 9	1710
L777	909	85 0	4250
L778	1140	56 3	3010
L779	1130	55 6	2780
L780	2640	155	8610
L781	2550	249	14600
L782	7470	220	13600
L783	4320	162	9180
L784	3490	151	8460
L786	1120	37 3	1960
L787	1250	67 2	3660
L788	934	46 9	2530
L789	615	9 3	633
L790	1640	77 3	4050
L791	3770	78 4	4220
L792	5560	78 7	5214
L793	1270	70 2	3980
L794	1100	84 6	4720
L795	10100	456	25200
L796	1380	47 2	2460
L797	1360	46 7	2630
L800	1710	80 5	4790
L801	1070	76 4	3010
L802	8230	278	15200
L803	13800	524	
L804	1440	69 2	3930

(Cont. nued)
TABLE 1
LITHIUM TAILINGS

Sample No	Metal Conc., ug/g		
	Pb	Co	Zn
L805	1740	69 6	3970
L806	2830	87 8	5380
L812	6200	177	9900
L813	4180	325	19600
L814	3521	147	8320
L815	4340	158	9570
L816	2490	137	8850

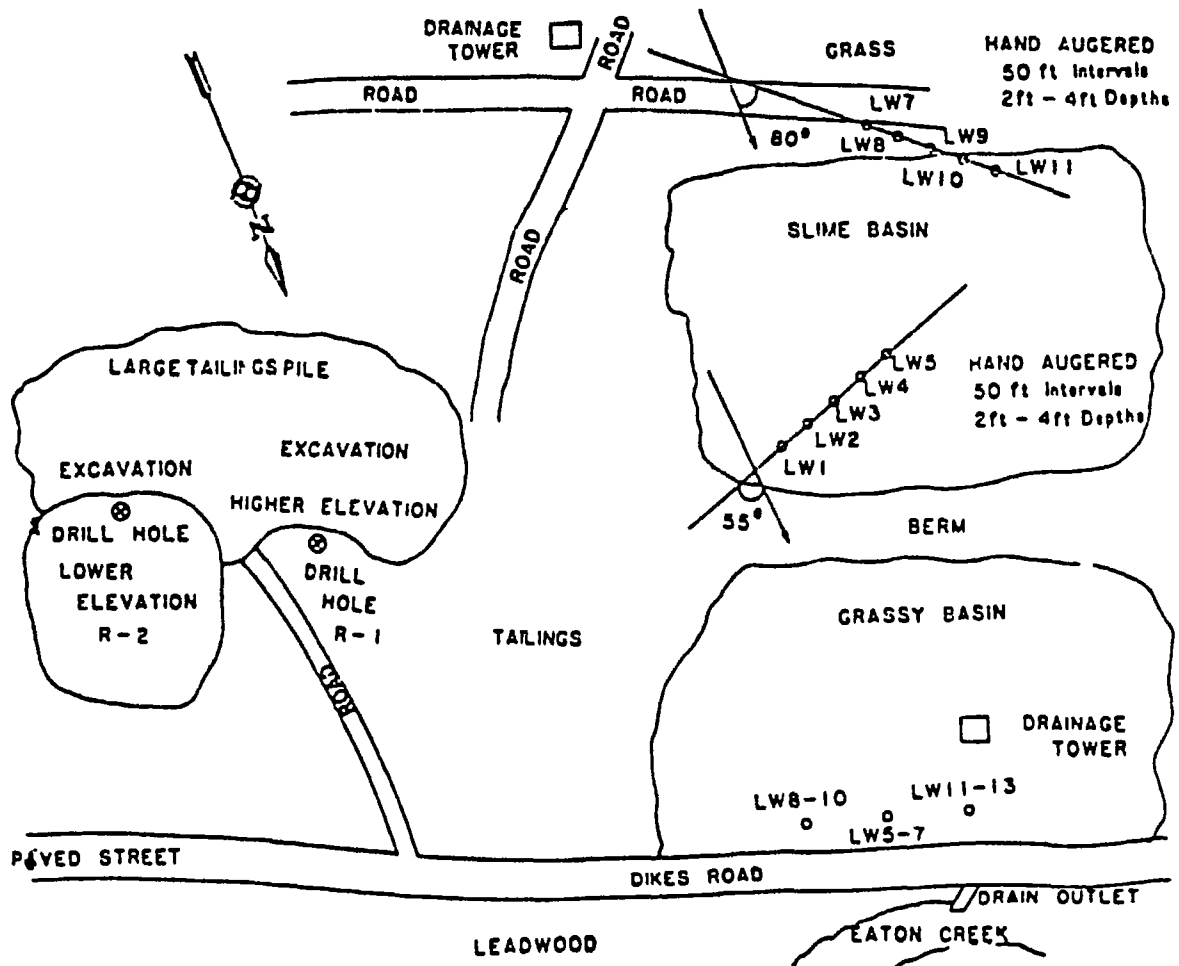


FIGURE 6 LOCATION OF U S BUREAU OF MINES AUGER AND CORE SAMPLING SITES ON LEADWOOD TAILINGS PILE

TABLE 2
AUGER AND CORE SAMPLING OF
LEADWOOD TAILINGS PILE (Courtesy Bureau of Mines)

Sample No	Metal Conc ug/g		
	Pb	Cd	Zn
<u>Surface</u>			
LW 5-7	2200	40	833
LW 8-10	2167	37	800
LW 11-13	2850	35	500
<u>Augered - Surface - two - four foot depth</u>			
LW 1-Surface	1300	40	1000
LW 1-2 ft	600	40	400
LW 1-4 ft	700	30	300
LW 2-Surface	1600	40	1200
LW 2-2 ft	2000	40	1100
LW 2-4 ft	2500	40	1300
LW 3-Surface	600	30	400
LW 3-2 ft	1200	40	1000
LW 3-4 ft	700	30	800
LW 4-Surface	1600	80	1300
LW 4-2 ft	3200	80	1300
LW 4-4 ft	4000	100	1800
LW 5-Surface	2000	130	1800
LW 5-2 ft	2400	100	1700
LW 5-4 ft	2800	110	1400
LW 7-Surface	1400	110	1000
LW 7-2 ft	1200	90	1300
LW 7-4 ft	1500	70	1400
LW 8-Surface	1400	50	1000
LW 8-2 ft	1500	80	1100
LW 8-4 ft	1600	80	1200
LW 9-Surface	1500	90	1200
LW 9-2 ft	1500	100	1000
LW 9-4 ft	1500	120	1300
LW 10-Surface	1300	40	1000
LW 10-2 ft	1000	40	1000
LW 10-4 ft	1900	60	1600
LW 11-Surface	2600	50	1200
LW 11-2 ft	1100	60	1700
LW 11-4 ft	1000	60	1400

TABLE 2 (Cont)
 AUGER AND CORE SAMPLING OF
 LEADWOOD TAILINGS PILE (Courtesy Bureau of Mines)

Sample no	Metal Conc, ug/g		
	Pb	Cd	Zn
<u>Rotary Cored</u>	<u>Pb</u>	<u>Depth</u>	
R-1	5000	3 ft	
	5100	6	
	5500	9	
	5200	12	
	4900	15	
	4500	18	
	4300	21	
	4600	24 - Bottom on tailings	
R-2	16600	3 ft	
	12100	6	
	10400	9	
	10500	12 - Bottom of tailings	

TABLE 3
 ROTARY CORE SAMPLING OF LEADWOOD TAILINGS DEPOSIT
 INDUCTIVE COUPLED ARGON PLASMA ANALYSIS (ICAP) FOR SITE R-1 BY DEPTH
 (UNITS ARE MICROGRAMS/GRAM)

Element	3 ft	6 ft	9 ft	12 ft	15 ft	18 ft	21 ft	24 ft
Ag	20	20	17	21	15	8	9	10
Al	830	820	1200	720	520	490	760	740
As	9	9	9	7	5	5	6	6
B	5	6	10	6	6	5	5	3
Ba	11	34	70	67	49	36	40	34
Be	0.89	1.0	1.1	0.96	0.83	0.83	1.0	0.9
Ca	190,000	190,000	180,000	180,000	190,000	190,000	190,000	190,000
Cd	250	270	180	170	160	130	120	120
Co	27	32	37	37	35	32	33	30
Cr	6.8	4.3	10	18	20	22	25	41
Cu	15	12	12	14	15	11	13	10
Fe	19,000	19,000	20,000	20,000	20,000	21,000	21,000	20,000
Li	2	1	2	1	1	1	1	2
Hg	100,000	100,000	99,000	100,000	100,000	100,000	100,000	100,000
Mn	3400	3400	3400	3500	3500	3600	3600	3500
Mo	20	20	20	30	30	30	30	20
Ni	16	18	18	23	18	18	23	16
P	190	200	210	210	210	200	190	190
Sb	9	8	9	9	10	10	9	9
Se	10	10	20	40	30	30	30	20
Si	180	340	160	250	210	140	100	110
Sn	<2	<2	<2	<2	<2	<2	<2	<2
Sr	50	52	50	50	50	51	50	51
Tl	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
V	4	4	4	4	4	4	4	3
Zn	13,000	14,000	9800	9600	8400	7300	6600	6300

TABLE 4
 ROTARY CORE SAMPLING OF LEADWOOD TAILINGS DEPOSIT
 INDUCTIVE COUPLED ARGON PLASMA (ICAP) ANALYSIS FOR SITE R-2 BY DEPTH
 (UNITS ARE MICROGRAMS/GRAM)

Element	3 ft	6 ft	9 ft	12 ft
Ag	23	30	27	24
Al	1800	1000	1100	760
As	10	10	10	10
B	10	8	3	<2
Ba	7 3	6 0	7 3	8 1
Be	1 1	1 0	1 0	0 66
Ca	160,000	170 000	170 000	150 000
Cd	350	450	430	420
Co	53	74	86	130
Cr	6 8	11	16	54
Cu	15	15	17	22
Fe	20 000	20,000	21,000	21 000
Li	3	2	2	1
Mg	90 000	90,000	90 000	82 000
Mn	3200	3200	3300	3000
Mo	20	30	30	30
Ni	25	37	50	67
P	240	230	240	270
Sb	9	7	4	<3
Se	10	20	10	10
Si	96	470	130	220
Sn	<2	<2	<2	<2
Sr	46	45	45	41
Tl	<0 3	<0 3	<0 3	<0 3
V	6	5	5	4
Zn	19 000	23 000	23,000	23 000

The rotary core samples were taken in the area where prior sampling had indicated that the chat contained elevated levels of metals and probably represented the oldest part of the deposit. The R-1 site was cored to the bedrock at the bottom of the pile which represented a depth of 24 feet. Samples were taken every three feet and analyzed for a complete host of elements by the ICAP method. Lead at this location did not show an increase toward the bottom of the hole but remained in the 4600 to 5000 ppm range. The water brought up in the coring samples was fresh and without any anaerobic smell which leads one to postulate that the rainwater leachate is moving away from the tailings pile to the drain at the northern edge of the tailings area. ICAP data also indicates that the concentration of other elements tends to remain fairly constant again indicating a more rapid flow through of rainwater with no appreciable concentrations at the bottom of the chat deposits.

The rotary core samples at site R-2 were started in a depression some 12 feet lower than the R-1 site and approximately 100 yards to the south of the R-1 site. Lead concentrations at the surface ran 16,600 ppm and decreased to 10,500 ppm at the 12 foot depth or bottom of the hole at dolomite bedrock. Again the water brought up with the samples did not contain any anaerobic odor and was of a quality that could be attributed to rainfall. The ICAP data for the R-2 site did not exhibit any unusual increases or decreases in the elements surveyed which seemed to further confirm the rapid penetration and subsurface flow of storm runoff water through the tailings pile and into the drain for Eaton Creek branch.

B Big River-Desloge

The Big River-Desloge tailings pile is located on a turn of the Big River approximately two miles downstream from Leadwood, Missouri and east of the town of Desloge, Missouri. During the past four years, this tailings pile received much attention from the regulatory agencies, researchers and the press due to a break in the elevated pile allowing for the discharge of tailings into the Big River along the eastern slope.

The Kansas City Times headline article of March 28, 1981 carried a banner headline saying "Old Mines Leave a Legacy of Danger" (13) which expressed concern about repairs to halt the runoff of lead.

The break has since been repaired but the instability of the tailings pile along the eastern slope and bordering the Big River remains to be a problem.

Figure 7 illustrates the sampling pattern employed in characterizing the Big River-Desloge tailings pile. Table 5 gives a listing for Pb, Cd and Zn concentrations found for the various sample sites. A total of 74 samples were taken to meet the statistical requirements suggested by the Missouri Department of Natural Resources (14).

C National

The National tailings pile is situated in the northern portion of Flat River, Missouri and is shaped like a large dome covering approximately 1.3 square km (0.5 square miles) in area. Storm water runoff from the tailings area is discharged into Flat River creek which flows some three miles before it discharges into the Big River.



FIGURE 7 LOCATION OF SAMPLING SITES (BIG RIVER-DESLOGE TAILINGS PILE)

TABLE 5
BIG RIVER-DESLOGE TAILINGS PILE

Sample No	Metal Conc ug/g		
	Pb	Cd	Zn
D900	1670	37 8	1670
D901	1540	38 9	1700
D902	1420	27 4	1150
D903	1190	11 7	330
D904	1420	54 8	2380
D905	2590	30 2	1320
D906	3840	34 9	1750
D907	3560	26 5	1380
D908	970	6 8	875
D909	1250	15 6	950
D910	1800	15 7	1040
D911	1360	25	1080
D912	2310	40 0	1890
D913	4470	18 3	821
D915	1530	13 8	680
D916	826	15 7	531
D917	3140	31 7	1440
D918	1020	17 4	637
D919	958	21 4	798
D920	2710	29 9	1380
D921	1570	8 0	511
D922	997	7 0	406
D923	835	8 0	373
D924	896	7 5	437
D925	1310	9 8	373
D926	1080	13	297
D927	983	11 8	354
D928	877	16 5	518
D929	964	13 8	373
D930	1380	15 0	582
D931	1010	18 5	698
D932	1150	21 5	816
D933	951	11 6	233
D934	1620	20 5	840
D935	5530	46 9	404
D936	1570	24 2	933
D937	1400	8 7	525
D938	1330	19 8	733
D939	1140	21 5	783
D940	2380	19 2	1380
D941	1120	9 2	558
D942	1410	15 4	715
D943	4320	68 2	3580
D944	1800	15 8	1210
D945	1710	21 1	1090

TABLE 5 (Cont)
BIG RIVER-DESLOGE TAILINGS PILE

Sample No	Metal Conc. ug/g		
	Pb	Cd	Zn
D946	3190	17 5	1350
D947	933	12 0	344
D948	1440	13 5	439
D949	2380	18 1	644
D950	1730	15 9	693
D951	1540	55 9	519
D952	1490	7 7	560
D953	1070	24 5	1030
D954	4710	31 4	1510
D955	2780	30 7	1570
D956	5360	28 8	1330
D957	6200	37 3	1720
D958	2910	37 1	1680
D960	1880	35 8	3990
D961	1830	39 4	3080
D962	1950	38 9	2910
D963	1410	32 9	1970
D964	2180	45 6	2500
D965	2130	43 8	1780
D967	1980	37 8	1720
D968	2310	37 9	1870
D969	1810	25 6	1100
D970	3610	38 2	1850
D971	5822	46 2	2250
D972	2240	22 9	994
D973	4070	44 5	2090
D974	2110	33 6	1560
D975	3130	51 6	2410
D976	2690	78 6-	3970

An extensive study was carried out on the National tailings pile for this project and resulted in a thesis entitled "Impact of Tailings from Abandoned Lead Mines on the Water Quality and Sediments of Flat River Creek and Big River in Southeastern Missouri" by Mr. Larry E. Elliott (15)

Figure 8 indicates the location of the sampling sites on the National tailings pile used for this study. A total of ninety three samples of tailings material was collected and analyzed for lead, zinc, cadmium, and copper. Seventy eight from the main pile, eight and seven from the erosion areas on the north and east sides, respectively as shown in Table 6. Table 7 provides a statistical analysis of the metal concentrations in each of the three areas.

Samples from the main pile were found to contain lead concentrations ranging from a low of 1640 ppm to a high of 9283 ppm, with values well distributed between these two extremes. Although samples taken in close proximity to one another often reflected similar concentrations with respect to the wide range of values encountered, no definite pattern seemed evident. The concentrations of lead appeared to be randomly dispersed from both the top to the bottom as well as around the perimeter of the pile. This random behavior was displayed by all four of the metals studied.

Zinc was found in concentrations generally ranging from 87 ppm to 978 ppm, with the exception of three samples which were found to be much higher. Two of these were just under 2000 ppm while the third, collected from the northwest side of the pile contained 5055 ppm of zinc.

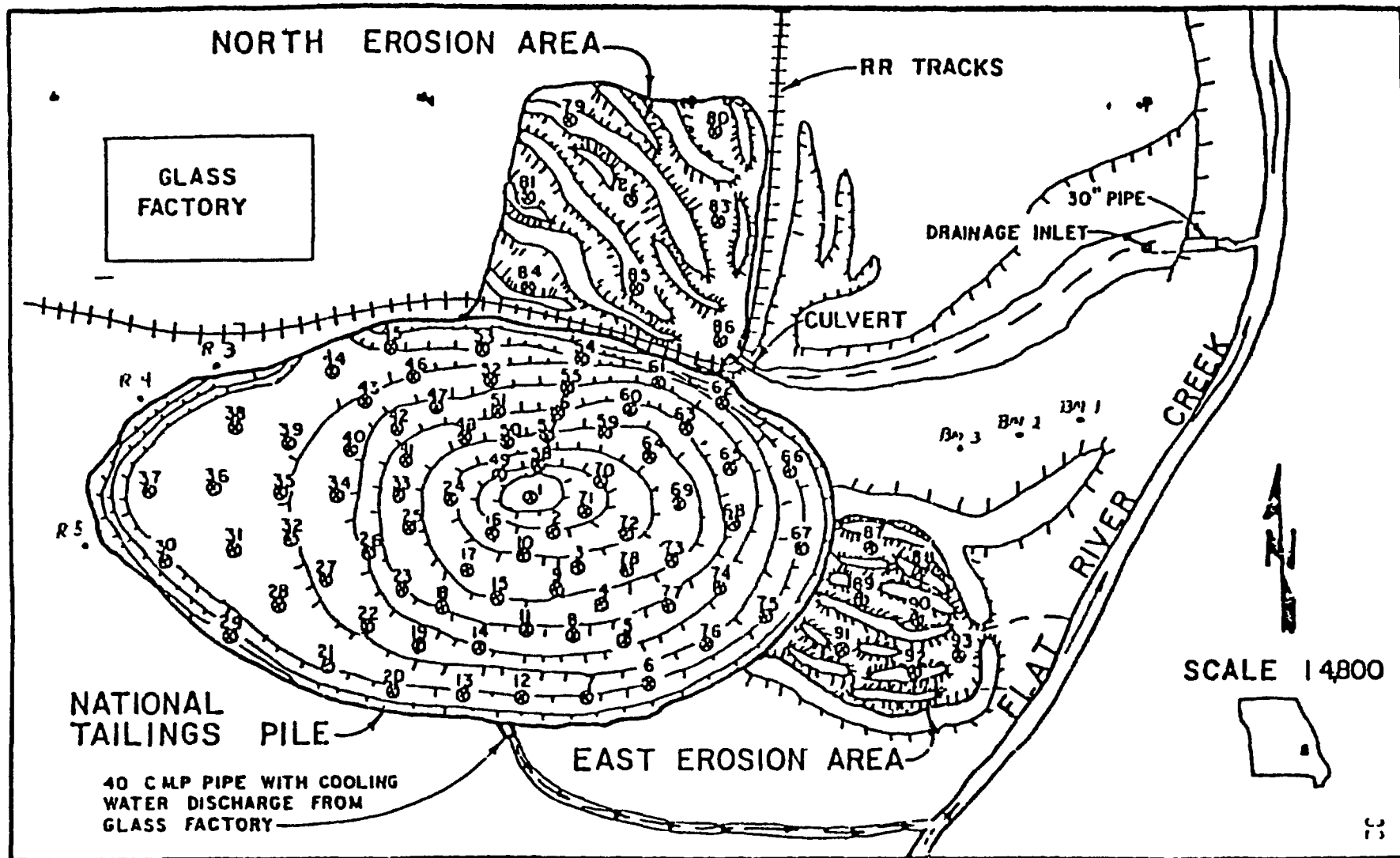


FIGURE 8 LOCATION OF SAMPLING SITES AT THE NATIONAL TAILINGS PILE (15)

TABLE 6
NATIONAL TAILINGS PILE (15)

Sample Number	Metals ppm			
	Pb	Zn	Cd	Cu
1	5261	518	7	133
2	4225	305	6	122
3	1815	240	5	65
4	1959	108	4	95
5	2377	95	3	92
6	4780	233	3	30
7	4822	289	3	115
8	1822	87	3	100
9	2585	90	3	133
10	2348	258	5	11
11	4044	496	8	244
12	2581	432	7	264
13	4566	628	8	183
14	3881	703	9	176
15	5376	865	12	95
16	2579	156	4	64
17	3880	471	6	67
18	2396	174	5	165
19	3166	312	6	358
20	4327	955	13	197
21	3242	469	7	102
22	4762	621	9	354
23	2570	188	4	227

TABLE 6 (Cont.)
NATIONAL TAILINGS PILE (15)

Sample Number	Metals ppm			
	Pb	Zn	Cd	Cu
24	2318	207	3	106
25	2413	722	11	63
26	2205	475	7	99
27	1678	454	7	154
28	4461	510	6	7
29	3504	436	5	220
30	4558	433	5	52
31	5341	547	6	413
32	2292	391	6	003
33	2189	245	4	91
34	1984	112	2	628
35	3007	314	4	215
36	3254	356	6	357
37	7101	1075	29	308
38	3519	403	6	330
39	2754	254	3	196
40	2854	217	7	109
41	2619	302	4	162
42	6746	1955	30	380
43	7766	1055	47	81
44	9293	626	10	182
45	2951	113	5	282

TABLE C (Cont)
NATIONAL TAILINGS P.L. (15)

Sample Number	Metals ppm			
	Pb	Zn	Cd	Cd
46	5141	439	6	305
47	3512	363	5	10
48	4853	183	4	287
49	2283	95	3	67
50	4908	460	6	110
51	2635	280	5	114
52	3186	449	6	51
53	2203	267	6	241
54	2157	253	5	181
55	5333	397	6	90
56	2063	112	3	81
57	5060	408	6	135
58	5519	587	7	136
59	2380	176	4	131
60	2268	978	12	142
61	2093	232	4	101
62	4115	271	5	95
63	1774	170	5	107
64	3369	385	6	110
65	2240	329	6	101
66	2004	222	5	49
67	2462	302	5	137
68	1821	48	3	105

TABLE 6 (Cont.)
NATIONAL TALLIES PILE (15)

Sample Number	Metal ppm			
	Pb	Zn	Cd	Cu
69	4732	493	7	129
70	6759	609	7	131
71	3274	321	7	113
72	3465	211	4	121
73	2420	387	6	115
74	1646	277	4	101
75	2368	234		111
76	1140	127	3	139
77	1117	156	4	126
78	1694	115	4	91
79	2477	30		44
80	2100	102	11	32
81	5494	398	8	98
82	1553	107	4	88
83	1177	34	3	53
84	3229	70	3	39
85	2774	30	4	36
86	1181	107	4	99
87	4641	127		122
88	5204	129	4	286
89	7991	245	7	64
90	9245	135	4	183
91	7047	192	5	70

TABLE 6 (Cont)
NATIONAL TAILINGS PILE (15)

Sample Number	Metals ppm			
	Pb	Zn	Cd	Cu
92	8818	1170	19	459
93	6315	72	3	181

TABLE 7
 STATISTICAL ANALYSIS OF HEAVY METALS
 IN THE NATIONAL TAILINGS PILE (14)
 Note All Values in ppm

	Lead	Zinc	Cadmium	Copper
NORTH TAILINGS PILE				
Mean	3508	457	7.2	183
Standard Deviation	1516	613	10.1	124
95% Confidence Interval	3172 < μ < 3844	94 < μ < 562	2.5 < μ < 10.3	102 < μ < 290
NORTH FROSTION AREA				
Mean	2510	112	4.9	61
Standard Deviation	1325	112	2.8	27
95% Confidence Interval	1592 < μ < 3428	29 < μ < 190	3.0 < μ < 6.8	42 < μ < 80
EAST FROSTION AREA				
Mean	6894	295	6.4	196
Standard Deviation	1464	361	5.3	127
95% Confidence Interval	5809 < μ < 7979	94 < μ < 562	2.5 < μ < 10.3	102 < μ < 290

Cadmium was generally low in concentrations compared to the other three metals. With the exception of sample number forty-three, containing eighty-seven ppm, all the samples contained concentrations of three to thirty ppm, inclusive. Sample number forty-three exhibited the highest value of zinc, and contained nearly 8000 ppm of lead. This sample was also adjacent to the tailings sample showing the highest lead concentration.

Copper concentrations ranged from 51 ppm to a high of 628 ppm with the samples being well distributed throughout these limits. Of the four metals, copper seemed to be the most random in distribution, with samples in close proximity even differing greatly from one another.

Although no definite pattern was observed for the distribution of the metals throughout the pile, a sample abundant in one metal tended to have high concentrations of the others, with the exception of copper. For example, tailings materials rich in lead would likely be rich in zinc and cadmium.

The north erosion area displayed lower average concentrations for all four metals when compared with the main pile and the east erosion area. A lead pattern of dispersion not apparent for the main pile was evidenced in this area. Samples on the west and southwest edge of this area were highest in lead, followed by steadily decreasing concentrations as the sample sites progressed eastward.

Even though the highest value for zinc (398 ppm) and lead was shared by the same sample, the pattern of dispersion found for lead did not occur with zinc, cadmium, or copper. Zinc was found almost exclusively to fall within the interval of 34 ppm low to 107 ppm high.

The values for cadmium ranged from 2 to 11 ppm, while copper ranged from 32 ppm to 99 ppm

Unlike material from the main pile, samples in the north erosion area that were rich in one metal did not generally correspond to high concentrations in any of the other three metals

The east erosion area contained the highest average concentrations for lead and copper and demonstrated a pattern of dispersion for lead, while zinc, cadmium, and copper failed to exhibit a recognizable pattern

Lead, up to a high value of 5818 ppm on the southern portion of the erosion area, and a low of 4641 ppm on the northern portion, tended to increase in concentration as the sample points progressed southward. The sample points going from east to west, however, differed only slightly in their respective concentrations of lead

Hand augered samples to a depth of 8 feet were made by the U S Bureau of Mines team for the north and east erosion area. Samples number BM-1, BM-2 and BM-4 were made in the tailings runoff area affected by storm water that ultimately drain into Flat River Creek to the east of the deposit. Augered samples were also taken in the vicinity of samples number 82, 89 and 90 in the erosion areas

Rotary core samples were taken to the bottom of the tailings piles at locations R-3, R-4 and R-5. All of these locations are noted in Figure 8. Table 8 indicates the auger and core samples by depth with concentrations of Pb, Cd and Zn. Table 9 gives the ICAP data for elements found at different depths for the R-3 and R-4 coring sites. Table 10 gives the rotary core ICAP analysis for site R-5 down to the clay layer underlying the pile at a depth of approximately eleven feet.

TABLE 8
AUGER AND CORE SAMPLES ON NATIONAL
TAILINGS PILE (Courtesy of Bureau of Mines)

Sample No		Metal Conc, ug/g		
		Pb	Cd	Zn
Hand Augered				
BM-1	Surface	1100	40	700
BM-1	2 ft	4100	20	300
BM-1	4 ft	4600	30	400
BM-2	Surface	4700	30	400
BM-2	2 ft	3800	30	300
BM-2	4 ft	2000	40	300
BM-3	Surface	2700	40	300
BM-3	2 ft	1900	40	200
BM-3	4 ft	1500	40	200
89	2 ft	2800	01.0	76
89	4 ft	3400	01.4	74
90	Surface	1800	2	78
82	2 ft	2100	1	28
82	4 ft	1100	5	270
82	6 ft	1200	3	150
82	8 ft	1200	1	40
82	Gully Side	760	1	42
Rotary Cored				
R-3	3 ft	7400	45	2700
R-3	5 ft	1400	15	1200
R-4	2-5 ft clay	6400	26	1200
R-4	3 ft chat	10200	72	3400
R-5	3 ft	9700	76	3700
R-5	6 ft	7100	120	6300
R-5	9 ft	8600	80	4100
R-5	10 ft	8300	88	5000
R-5	11 ft bottom clay	820	220	330

TABLE 9
 ROTARY CORE SAMPLING OF NATIONAL TAILINGS
 DEPOSIT INDUCTIVE COUPLED ARGON PLASMA ANALYSIS
 (ICAP) FOR SITES R-3 AND R-4 BY DEPTH
 (UNITS ARE MICROGRAMS/GRAM)

Element	R-3		R-4	
	3 ft	5 ft	2 5 ft	3 ft
Ag	9	4	8	7
Al	3500	16,000	1300	8000
As	<2	<8	8	<2
B	6	<8	3	7
Ba	29	104	8 1	66
Be	1 2	0 73	1 5	0 92
Ca	140,000	31,000	170,000	130,000
Cd	45	15	72	26
Co	150	30	180	61
Cr	9 5	26	3 9	10
Cu	58	45	96	29
Fe	34,000	30,000	41,000	29,000
Li	4	8	2	7
Mg	69,000	16,000	64,000	70,000
Mn	3800	2300	4600	3400
Mo	40	<8	50	40
Ni	97	31	150	56
P	260	320	270	280
Sb	<3	<17	<3	<3
Se	50	<17	30	30
Si	180	410	86	450
Sn	<2	<8	<2	<2
Sr	32	12	37	35
Ti	20	180	<0 3	54
V	10	39	5	18
Zn	2700	1200	3-00	1200

TABLE 10
 ROTARY CORE SAMPLING OF NATIONAL TAILINGS DEPOSIT
 INDUCTIVE COUPLED ARGON PLASMA (ICAP) ANALYSIS FOR
 SITE R-5 BY DEPTH
 (UNITS ARE MICROGRAMS/GRAM)

Element					
	3 ft	6 ft	9 ft	10 ft	BOTTOM CLAY 11 ft
Ag	10	10	8	8	0 7
Al	1100	1100	1500	1800	4200
As	6	6	9	20	20
B	20	<2	10	7	3
Ba	4 5	5 9	7 2	13	19
Be	1 5	1 4	1 5	1 2	0 2
Ca	180,000	170,000	170,000	160,000	98 000
Cd	76	120	80	88	220
Co	78	76	93	100	4 8
Cr	3 2	7 0	14	22	6
Cu	130	72	99	83	6 8
Fe	39,000	31,000	35,000	34,000	6400
Li	2	2	3	2	3
Mg	90,000	86 000	85,000	81 000	57 000
Mn	4700	4300	4400	4200	550
Mo	50	40	50	40	<2
Ni	67	49	72	77	6 0
P	280	360	340	370	90
Sb	<3	<3	<3	<3	<3
Se	30	30	40	30	<3
Si	130	220	130	130	170
Sn	<2	<2	<2	<2	<2
Sr	40	40	<0 03	38	30
Ti	<0 3	<0 3	<0 3	2	32
V	4	4	5	7	11
Zn	3700	6300	4100	5000	330

The samples BM-1, BM-2 and BM-4 in the drainage pattern reflect the tailings transport from the north erosion area and part of the main dome-like structure of the main pile. The lower lead values shown for the two erosion areas reflect the slime pool discharges that had more of the lead removed during processing.

The rotary core samples were made along the edge of the older chat material at the western side of the main tailings pile. It was known that the chat material in this area averaged around 8000 to 10,000 ppm lead and we wanted to determine what the depth of the chat materials was in this area. The deposit turned out to be thinner than thought in most areas (3-5 feet deep) where people had been hauling the chat away for road material or use as agricultural limestone. The clay layer underlying the deposit had low lead and zinc values but increased cadmium levels (up to 220 ppm) which were significantly higher than concentrations normally found in the tailings, chat or slime line materials.

Water brought up with the core samples did not exhibit an anaerobic or methane odor again suggesting that rainwater percolates through the chat and tailings materials and then moves horizontally along the top of the clay materials and drains into Flat River Creek.

D Elvins

The Elvins tailings pile borders northern Elvins, Missouri and covers a land area of approximately 0.6 square km (0.25 square miles). Two shallow lakes are found on the southwestern edge of the tailings pile and seepage from the base of the deposit passes through these shallow lakes and then flows into Flat River Creek. These waters

contain high levels of dissolved calcium, magnesium, zinc and lead which have an impact on the sediments and biota of Flat River Creek

The Elvins tailings pile was studied in 1976 by Kramer (16) and the growth of algae in the zinc rich wastes and seepage water has been reported by Whitton, et al (17). Presently a small asphalt paving plant operates on the southern perimeter of the tailings pile with the tailings being used as a finer sized aggregate source

Figure 9 illustrates the location of 91 sampling sites on the Elvins tailing pile. Table 11 gives the metal concentrations of Pb, Cd and Zn found at the sampling locations

E Bonne Terre

The Bonne Terre tailing deposits consist of two different areas and configurations. A large chat and tailings dome is situated on the east side of Bonne Terre, Missouri and covers an area of approximately 50 acres of land. The second area is located about 1/2 mile to the west of the chat hill just across Missouri Highway 67 and is a mostly dried-up tailings pond covering about 272 acres.

Figure 10 gives the location of sampling sites on the Bonne Terre tailings pile which is shaped like a small hill overlooking a golf course. Table 12 lists the metal concentrations found for Pb, Cd and Zinc at the tailings pile.

Figure 11 shows the location of sampling sites on the flat tailings deposits of the Bonne Terre east deposit which still has water confined at one end. Table 13 gives the metal concentrations found for Pb, Cd and Zn at the recorded sampling locations.

F Statistical Analysis of Different Tailings Piles

Heavy metal data from the characterization of the different tailings and chat piles studied were statistically evaluated for

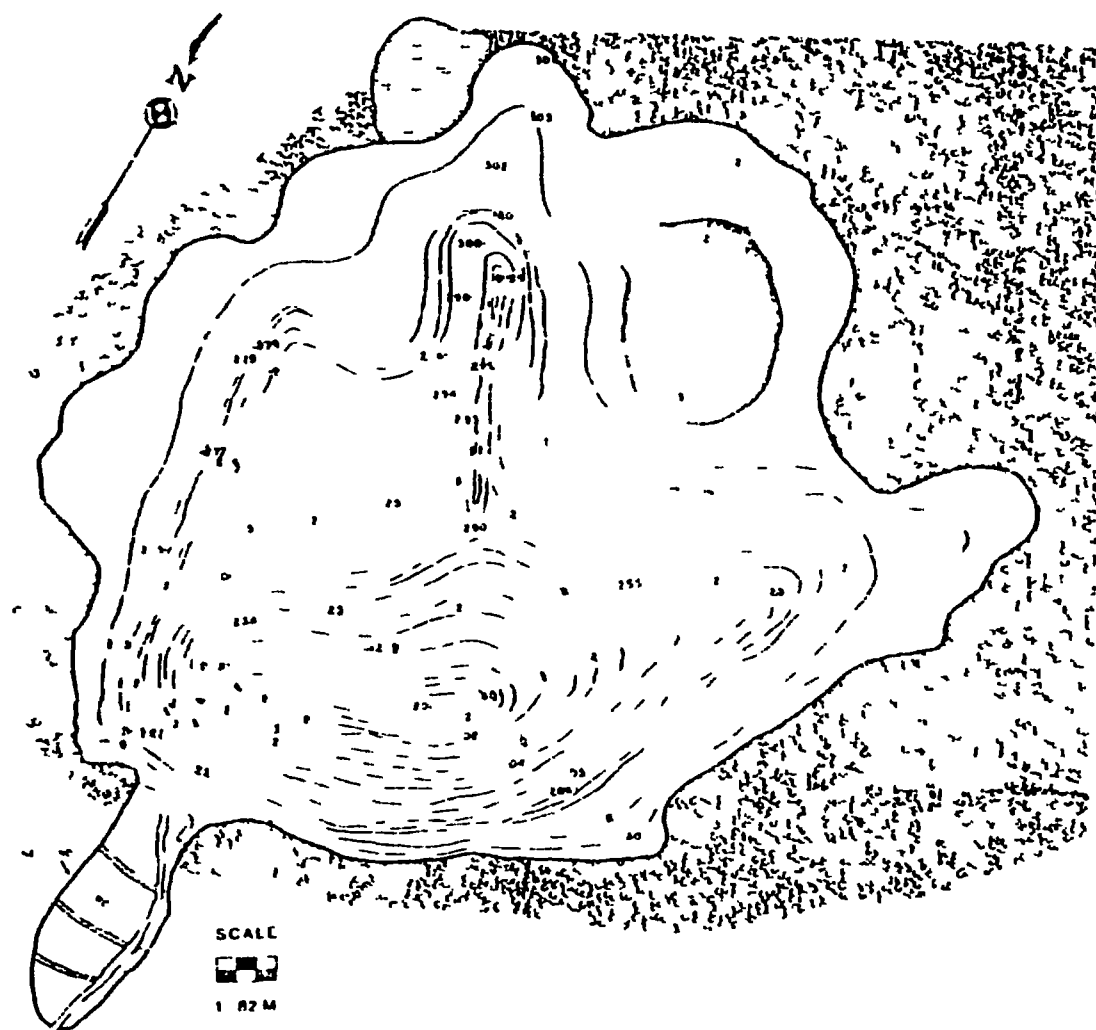


FIGURE 9 LOCATION OF SAMPLING SITES ON ELVINS TAILINGS PILE

TABLE - 11
ELVINS TAILINGS PILE

Sample No	Metal Conc ug/g		
	Pb	Cd	Zn
E200	5990	190	6100
E201	6420	180	11200
E202	7950	202	11200
E203	5130	199	10600
E204	4460	165	9210
E205	4200	156	8620
E206	4400	168	9510
E207	3570	140	8210
E208	3650	152	8180
E210	5180	171	11800
E211	4190	179	11400
E212	6000	153	9600
E213	4630	160	9630
E214	5450	155	8610
E215	6780	156	8080
E216	6960	172	9260
E217	5240	120	6870
E218	4980	114	6000
E219	7500	106	5600
E220	4760	168	10500
E221	6820	163	11400
E222	5500	110	6400
E223	5990	114	6100
E224	4470	70 8	4350
E225	5270		8590
E226	4010	92 9	5320
E227	1880	51 5	1290
E228	3680	84 6	5150
E229	5180	132	6480
E230	4550	76 3	6540
E231	4300	189	11900
E232	3880	138	8820
E233	3170	151	2040
E234	2780	126	6510
E235	3630	112	6090
E236	3180	92 5	4560
E237	1300	79 6	4470
E238	8140	106	1760
E239	8360	135	9280
E240	6200	84 0	4290
E241B	8000	95 0	1300
E242	9600	157	10900
E245	11100	91 8	4950
E246	5640	161	9680
E247	7080	159	8360
E248	3780	144	7870
E249	4600	129	6990

TABLE - 11 (Cont)
ELVINS TAILI GS FILE

Sample No	Metal Conc, ug/g		
	Pb	Cd	Zn
E250	6410	138	2040
E251	6190	114	6290
E252	4850	127	7020
E253	4050	118	6340
E254	4440	115	5360
E255	1700	51 3	2480
E256	2750	52 8	2210
E257	1350	48 3	2290
E258	1170	45 0	2190
E259	2180	54 4	2440
E260	2750	69 8	3300
E261	1060	61 4	2170
E262	1400	110	5500
E263	1270	74 8	3570
E264	1120	72 2	3230
E265	1620	75 5	3770
E266	4230	119	1440
E267	1060	74 7	3620
E268	1050	74 8	3660
E269	991	58 2	2140
E270	851	57 9	2600
E271	1100	74 7	2650
E272	4190	82 3	4240
E273	8890	85 0	4250
E274	4890	63 9	3290
E275	7160	100	4810
E276	9310	19 8	792
E277	9260	31 5	1950
E278	10000	134	8510
E279	11600	163	10900
E280	7200	94 4	5960
E290	4020	62 9	3510
E291	2750	56 1	3000
E292	2890	50 2	2330
E293	1080	41 7	2450
E294	2940	67 6	3380
E295	2190	75 8	3980
E296	2230	99 1	5820
E297		59 3	3600
E298	1890	48 4	2610
E299	3160	61 7	3210
E300	2270	47 3	2360
E301	2080	54 4	2230
E302	1780	42 2	1990
E303	1650	44 9	2120
E304	1900	42 6	108

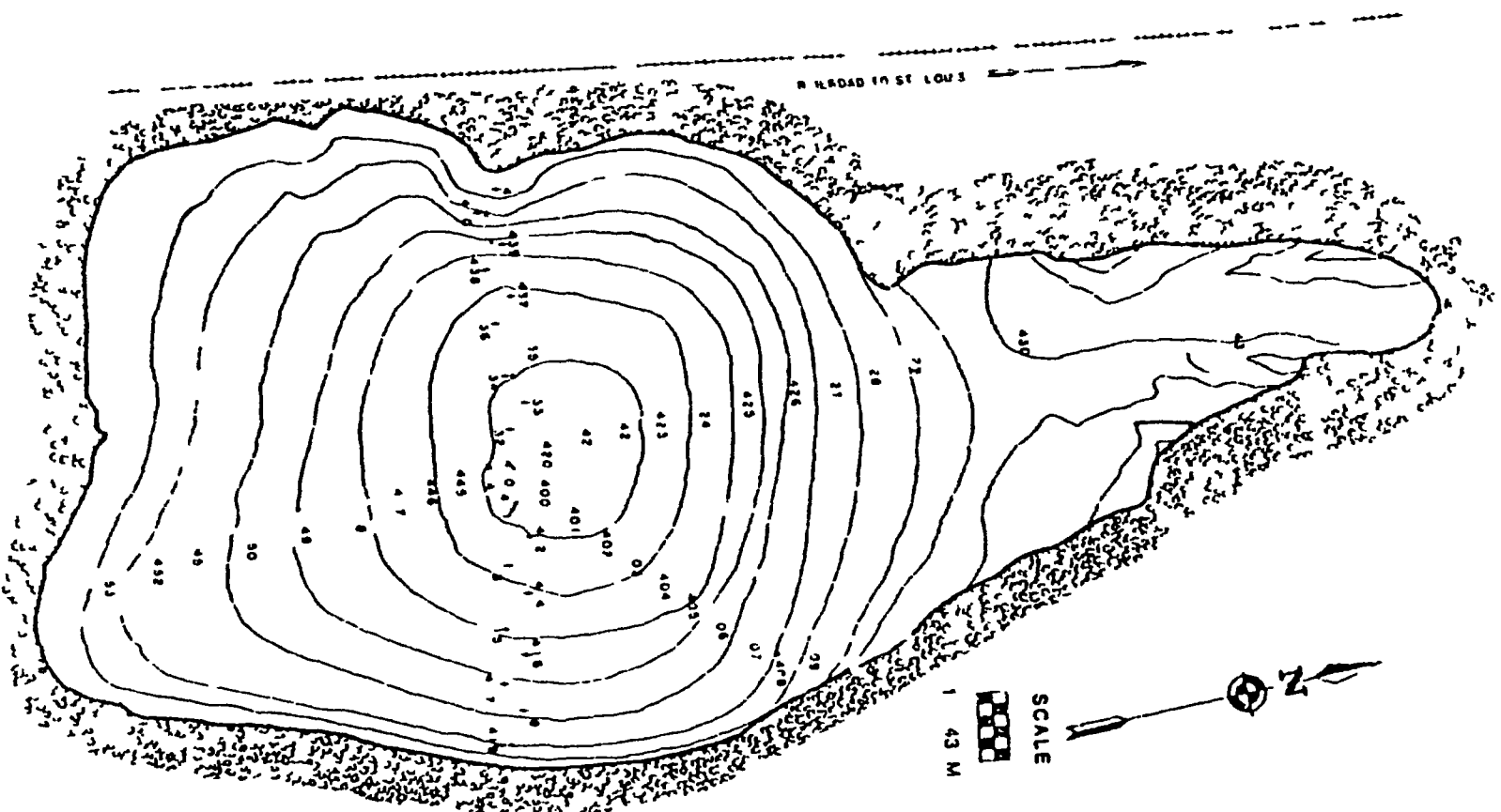


FIGURE 10 LOCATION OF SAMPLING SITES ON BONNE TERRE
TAILINGS PILE

TABLE - 12
BOVNE TERRE TAILINGS PILE

Sample No	Metal Conc. ug/g		
	Pb	Cd	Zn
BT400	5330	9 7	469
BT401	5020	5 4	273
BT402	1300	10 2	309
BT403	2020	9 9	430
BT404	2280	11 7	451
BT405	3540	11 9	689
BT406	3070	12 1	718
BT407	1890	17 6	650
BT408	1540	12 3	587
BT409	3230	14 9	501
BT410	3590	13 9	51 3
BT411	4120	13 4	671
BT412	4450	17 7	757
BT413	3140	14 4	722
BT414	4350	12 0	309
BT415	2540	16 1	757
BT416	3040	16 4	648
BT417	1630	9 6	486
BT418	1840	13 7	597
BT419	1760	10 0	641
BT420	1480	3 0	150
BT421	3080	5 5	194
BT422	2050	13 3	434
BT423	1940	13 0	479
BT424	2190	13 5	458
BT425	2380	15 1	573
BT426	2390	17 2	622
BT427	1580	15 1	553
BT428	1860	14 2	686
BT429	1340	13 9	661
BT430	4720	29 5	786
BT431	2650	7 0	150
BT432	3200	15 2	705
BT433	3200	15 8	650
BT434	7010	8 2	426
BT435	6670	15 3	477
BT436	5820	10 9	361
BT437	5210	18 1	559
BT438	4290	11 5	573
BT439	6730	13 6	755
BT440	6840	12 8	618
BT441	5800	16 0	180

TABLE - 12
BONNE TERRE TAILINGS PILE

Sample No	Metal Conc, ug/g		
	Pb	Cd	Zn
BT444	3280	15 1	511
BT445	4530	13 6	444
BT446	4220	17 4	697
BT447	5030	19 2	746
BT448	5980	22 5	967
BT449	5190	28 8	623
BT450	3390	22 4	922
BT451	3540	22 0	878
BT452	2791	15 7	563
BT453	6230	10 4	539

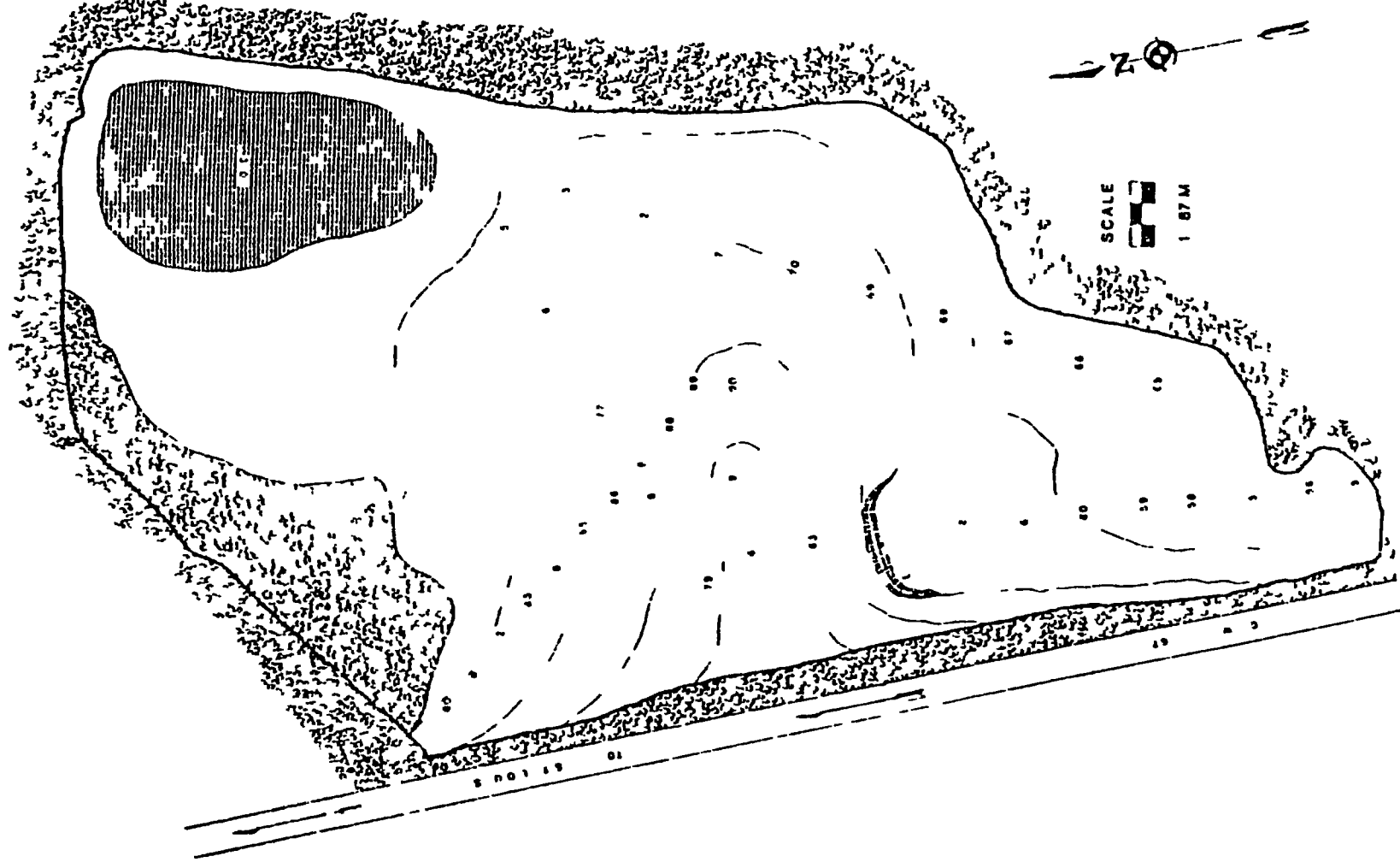


FIGURE 11 LOCATION OF SAMPLING SITES ON BONNE TERPE
TAILINGS FLAT

TABLE 13
BONNE TERRF TAILINGS FLAT

Sample No	Metal Conc, ug/g		
	Pb	Cd	Zn
BT455	1232	5 9	173
BT456	3020	10 2	361
BT457	6650	10 5	312
BT458	1810	5 9	385
BT459	1600	9 0	354
BT460	1920	12 3	491
BT461	1170	9 3	312
BT462	1610	10 0	234
BT463	989	8 4	185
BT464	1560	7 3	205
BT465	1550	11 2	244
BT466	2310	12 0	380
BT467	1540	10 8	366
BT468	3450	10 4	243
BT469	1620	9 5	255
BT470	1860	6 0	157
BT471	1520	4 5	87 2
BT472	2710	6 3	222
BT473	1170	3 6	99 5
BT474	660	7 9	151
BT475	1440	4 7	156
BT476	2610	4 9	330
BT477	1320	6 0	165
BT478	1900	13 2	337
BT479	1760	9 8	273
BT480	1290	13 8	524
BT481	1480	15 1	543
BT482	1780	13 3	321
BT483	1820	5 6	618
BT484	1400	6 7	171
BT485	2840	10 0	1470
BT486	7610	20 9	698
BT487	1590	6 7	152
BT488	1020	6 4	115
BT489	1950	8 1	321
BT490	1120	5 2	170

differences in Pb, Cd and Zn Table 14 shows the results of this evaluation The chat and tailings piles may be segregated by metal composition and this information could be most useful in considering stabilization, use as agricultural limestone or for road material, or for possible contributions to sediments of the Big River through stormwater runoff

The east erosion area of the National tailings pile contained the highest mean average of 6894 ppm Pb but a low Cd and Zn concentration The Elvins pile contained the second highest mean lead values of 4392 ppm coupled with the highest zinc values of 5482 ppm

The Leadwood deposit contained the highest cadmium values of 267 ppm coupled with the second highest zinc values of 5009 ppm It was of interest to note that the Big River-Desloge pile has the lowest mean lead values of 2077 coupled with average cadmium and zinc concentrations

These concentrations of metals may be compared with the values found in tailings from the Viburnum Trend or New Lead Belt with an average of 320 ppm lead, 8 ppm cadmium and 500 ppm zinc reflecting the increased efficiency of the flotation process presently in use by the mining industries

These values help to explain, in part, the impact due to the physical transport of tailings materials on Big River and Flat River Creek These impacts had been studied by Zachritz (18) and others (12) concerned with the concentrations and distribution of heavy metals in the sediments of the Big River which have contributed to a problem with lead in tissues of bottom feeding suckers (19)

TABLE 14
 STATISTICAL ANALYSIS OF HEAVY METALS
 IN THE DIFFERENT TAILINGS PILES

LEADCADMIUMZINCLEADWOOD →

Mean	2444	267	5009
Standard Deviation	4072	394	4894
95% Confidence Interval	2455 < u < 3231	223 < u < 299	4957 < u < 5894
Maximum	17000	1870	25800
Minimum	597	9 3	633

BIG RIVER DESLOGE

Mean	2077	26	226
Standard Deviation	1294	15 2	860
95% Confidence Interval	1931 < u < 2224	24 < u < 28	1129 < u < 1323
Maximum	6200	78 6	3990
Minimum	826	6 8	233

NATIONAL

Mean	3508	7 2	457
Standard Deviation	1516	10 1	613
95% Confidence Level	3172 < u < 3844	2 5 < u < 10 3	94 < u < 562

1) NORTH EROSION AREA

Mean	2510	4 9	112
Standard Deviation	1325	2 8	112
95% Confidence Interval	1592 < u < 3428	3 0 < u < 6 8	29 < u < 190

2) EAST EROSION AREA

Mean	6894	6 4	295
Standard Deviation	1464	5 3	361
95% Confidence Interval	5809 < u < 7979	2 5 < u < 10 3	94 < u < 562

ELVINS

Mean	4392	103	5482
Standard Deviation	2581	47 1	3179
95% Confidence Interval	4130 < u < 4654	98 < u < 108	5162 < u < 5803
Maximum	11600	202	11900
Minimum	851	19 8	108

BONNE TERRE

Mean	3515	13 9	541
Standard Deviation	1705	5 3	211
95% Confidence Interval	3285 < u < 3744	18 2 < u < 14 6	512 < u < 569
Maximum	7010	29 5	967
Minimum	1300	3 0	51 3

Elliott (15) and Wixson et al (12) have noted that the tailings materials tend to move downriver during storm events with the heavier metal rich fraction tending to settle out first as the storm water event decreases. This accounts for pulses of metals that may be found at different locations following periods of elevated rainfall and rapid runoff into and down the Big River.

Considering the amount of sediments found in the intestines of bottom feeding suckers, the bioavailability of lead and other metals in the sediments is rather small. However, continued monitoring is needed to make sure that lead levels in edible fish tissues do not approach levels of concern to human health.